Efficiencies and Inefficiencies of Scale

Those of you with an unbreakable tendency to stay up late, with the television talking to itself in the other room, have seen the monster films of the '50's. Well, whatever your concerns over monster bugs, worms grown large enough to devour cities, and earth pounding giants, I can assure you there is no need to worry. It's not just that I've looked around and found no footprints in the mud, it is that some things really are impossible.

Consider the case of the giant worm. Now worms, even those with aggressive tendencies have certain base line tasks to handle, like eating and breathing. If you are a worm then the way you breath is through that nice moist skin. This is where oxygen is absorbed from the outside and where other gases are released.

Now suppose that a giant film director takes charge of your wormly fate and finds some way of making you twice as large, not by moving the camera in to half the distance, but really making you twice as large. Here's what happens: You become twice as long. You are twice as wide, you are twice as high. That means that you weight two times two times two times as much as you did before. Twice as big implies eight times as much meat on the body. That means you have to take in about eight times the oxygen and release eight times the waste.

So, you've got to process about eight times as much air as before and, being a worm, you are going to do it through your skin. How much skin have you got to work with? Well, allowing that the cross section of a worm is roughly circular, your diameter increased by a factor of 2 so your circumference has increased by a factor of 2. Alowing that you are now twice as long, your skin surface will have increased four fold: Your mass (in need of oxygen) has increased eight times fold but your skin has increased only four fold.

Now, of course, increasing the diameter of an earth worm from one eighth of an inch to one quarter of an inch would be quite an event in the

life of the worm, but it would still be nothing in the competition among midnight film monsters. So, suppose the worm is be ten times larger than normal: A one meter long earth worm should create at least a little alarm. This worm, is now ten times wider, ten times higher, and ten times longer. He has 1,000 times the meat, but only 100 times the skin. The ratio of meat to air exchaning skin has dijminished ten fold. “Breathing” is going to be a problem.

Do that to the worm in one generation, by a horror induced mutation and it will die, literally, of its own weight long before it has terrified too many citizens. However, given a few tens of millions of years to accomodate to this transition, the worm might evolve a more convoluted skin, increasing its surface. It might protect all that convoluted moist skin by some sort of protective structure. And it might develop a mechnism for drawing the outside air over this protected convoluted moist skin — which might end up looking pretty much like a lung.

The film of this evening features a giant ant, born in the Nevada deserts (near the test sites) which, according to the film’s scientist (he’s wearing the white coat) is “two meters in length, that’s more than nine feet”. Bad start. Whatever: He is roughly 400 times the length of your garden variety ant. That’s 64,000,000 times the weight and he’s got to carry that weight on legs that are probably still a bit spindly at about an inch. Since the carrying capacity of a column (his leg) is proportional to its cross section, this guy is going to need leg splints, or some leg transplants from a hippopotamus.

The constraints by which form and function become related are referred to as “allometry”, the study of form. (D’Arcy Wentworth Thompson citation ***) In biology (and engineering) there are compelling lawful by which the extension of an object, the surface of the object, and the mass of the object are necessarily closely related innon-linear relations.

In the more social of the sciences, the principles of form create questions. If the dense population centers of San Francisco were to spread over more of the ground (in two dimensions) andperhaps go high

rise (in a third dimension), and if the flow through traffic arteries had to keep pace by creating wider and wider freeways (in one dimension), then you would have to pave the peninsula to supply transportation. Maybe.

Or consider, what is the ratio (or, perhaps, the optimal ratio) of administrators to students or administrators to faculty in a University? How is it related to size? I would think that if you took one well run university of 5,000 students and ran it up to 10,000 students then, at the worst, the ratio of administrators to students would remain constant: After all, the worst case would be siimply running the 10,000 student entity as two 5,000 student universities, doubling everything and leaving t he ratios intact. Anything better would be an economy of scale. Anything less would be a pathology of scale.

Consider: Does a ten fold difference in the size of two steel companies correspond to a ten fold increase in the number of employees or a ten fold increase in its capital assets? (Is there a change in the production function related to size?) Does a ten fold difference in the size of two cities correspond to a ten fold difference in the cost / taxes / police force / roads ? Is it more or less than ten fold? Does a ten fold difference in the size of two nations correspond to a ten fold increase in the sizes of their military forces? More or less?

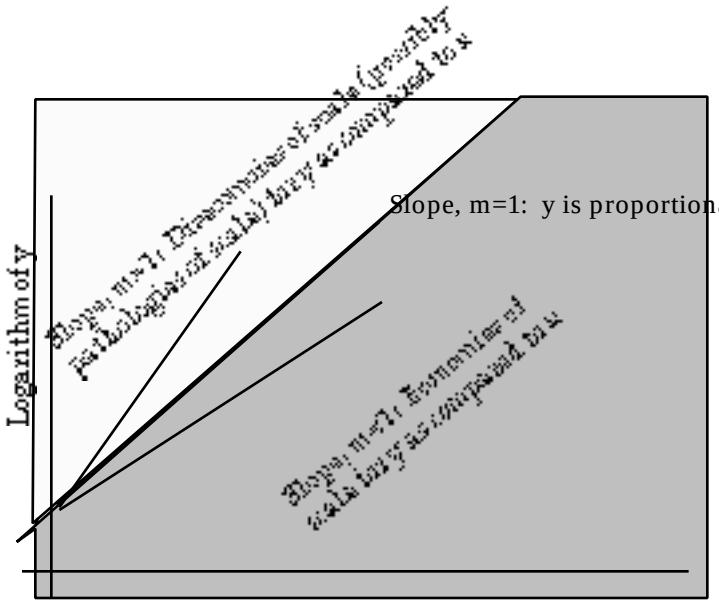
When you hear a question framed in the form does an a-fold increase in this correspond to a b-fold increase in that, you have entered the domain of log log graphs.

Where $\log(y) = m \log(x)+b$ the easy case is $m=1$ (at least approximately). Then y is directly proprotional to x. At $m=1$, the slope in the log log curve establishesthe direct proportionality. The intercept establisheds the proportion. And the size of the residuals works exactly the way it did in the semi-log graph: The residuals are residuals with respect to log y and they specify the factors by which the residuals lie above or below the predicted values.

Where $\log(y) = m \log(x)+b$ with $m>1$, comparing one case to another differences in y variable are proportionately greater than

differences in the x variable. The slope establishes the relation. E.g., m=2 implies that differences in y correspond to differences in the square of x. The intercept establishes the comparison at one reference point, log x = 0, x =1. And the residuals again specify the factors by which the residuals lie above or below the predicted values.

Where log(y) = m log (x)+b with m<1, differe3nces in the y variable are proportionately less than differences in the x variable. For example, if you were comparing the number of employees to the dollar assets of a steel company, for a wide range of steel companies, then with y = assets, m>1 would tell you that large steel companies are more asset/capital intensive than small steel companies. m<1 would tell you that large steel companies are more labor intensive than small steel companies. And m=1 would tell you that the production function governing the mix between capital and labor was unrelated to size.



Slope, m=1: y is proportional to x.

Exercises:

Describe the relation between the weight of the body and the weight of the lungs as implied by Spector's data.

#	Species	Sex & Number	Body Wt. KG	ln(Body Wt)	Brain grams	Ln(Brain)	Heart Grams	LN(Heart grams)	Liver Grams	LN(Liver)	Lungs Grams	Ln(Lungs)	Weig (pou @2.2 poun per kilogr
1	Man (Homo sapiens) Australian aborigine	M1	76	4.331	1345.2	7.204	0	????	0	????	0	????	1
2	Man (Homo sapiens) Chinese	M1	84	4.431	1478.4	7.299	554.4	6.318	2041.2	7.621	0	????	1
3	Man (Homo sapiens) Filipino	M1	43	3.761	1105.1	7.008	197.8	5.287	0	????	0	????	
4	Man (Homo sapiens) Indian, Maya Quiche	M1	42	3.738	1268.4	7.146	218.4	5.386	1041.6	6.949	1314.6	7.181	
5	Man (Homo sapiens) Indian, Maya Quiche	F1	46	3.829	1002.8	6.911	225.4	5.418	0	????	0	????	1
6	Man (Homo sapiens) Negro	F7	47	3.850	1283.1	7.157	380.7	5.942	1320.7	7.186	0	????	1
7	Man (Homo sapiens) White, American	F4	49	3.892	1239.7	7.123	313.6	5.748	1127	7.027	357.7	5.880	1
8	Man (Homo sapiens) White, European	F4	49	3.892	1239.7	7.123	313.6	5.748	0	????	0	????	1
9	Agouti (Dasyprocta punctata)	FM 5	2.6	0.956	15.08	2.713	13.26	2.585	73.84	4.302	5.72	1.744	

10	Antbear (Cyclops didactylus)	?1	0.09	-2.408	4.293	1.457	0	????	0	????	0	????	0.2
11	Anteater (tamanduas tetradactyla)	MF 4	2.2	0.788	23.98	3.177	0.66	-0.416	58.08	4.062	23.1	3.140	4.8
12	Armadillo (Dasypus novemcinctus)	MF 12	3.3	1.194	8.25	2.110	9.24	2.224	0	????	23.1	3.140	7.2
13	Ass (Equus asinus)	F1	150	5.011	405	6.004	825	6.715	1260	7.139	1245	7.127	330.6
14	Bat. vampire (Desmodus rotundus)	MF 5	0.02 8	-3.576	0.9352	-0.067	0	????	0	????	0	????	0.0
15	Bear, brown (Ursus americanus)	F1	550	6.310	0	????	0	????	0	????	0	????	1,212.5
16	Bear, grizzly (U. horribilis)	F1	140	4.942	224	5.412	1106	7.009	0	????	0	????	308.6
17	Beaver (Castor canadensis)	M1 F1	5	1.609	22.5	3.114	21.5	3.068	151.5	5.021	48.5	3.882	11.0
18	Bison, American (Bison bison)	F1	55	4.007	335.5	5.816	363	5.894	698.5	6.549	1193.5	7.085	121.2
19	Buffalo, African (Syncerus caffer)	M3 F1	700	6.551	630	6.446	3290	8.099	6860	8.833	6580	8.792	1,543.2
20	Bushbok (Tragelaphus scriptus)	M1 F1	44	3.784	162.8	5.093	334.4	5.812	858	6.755	721.6	6.581	97.0
21	Camel, bactrian (Camelus bactrianus)	M1	450	6.109	540	6.292	0	????	0	????	0	????	992.0
22	Caribou, ground (Rangifer arcticus)	M3 F1	98	4.585	294	5.684	882	6.782	1793.4	7.492	2058	7.629	216.0
23	Cat, domestic (Felis catus)	M7 F3	3.3	1.194	25.41	3.235	14.85	2.698	118.47	4.775	34.32	3.536	7.2
24	Cattle, Holstein (Bos taurus)	M5	900	6.802	450	6.109	3330	8.111	8280	9.022	6210	8.734	1,984.1

25	Cattle, Holstein (B. taurus)	F198	600	6.397	420	6.040	2220	7.705	7200	8.882	4320	8.371	1,3
26	Cheetah (Acinonyx jubatus)	F2	21	3.045	81.9	4.405	107.1	4.674	676.2	6.516	243.6	5.496	
27	Chimpanzee (Pan troglodytes)	M1	52	3.951	436.8	6.079	249.6	5.520	0	????	0	????	1
28	Chimpanzee (P. troglogytes)	F1	44	3.784	325.6	5.786	220	5.394	1210	7.098	598.4	6.394	
29	Chipmunk (Tamias striatus)	F2	0.07	-2.659	2.072	0.729	5.572	1.718	5.18	1.645	0.672	-0.397	
30	Coati (Nasua nasua)	M2	5.1	1.629	33.66	3.516	19.38	2.964	83.13	4.420	23.97	3.177	
31	Coyote (Canis latrans)	F2	8.5	2.140	0	????	72.25	4.280	292.4	5.678	61.2	4.114	
32	Deer, white-tailed (Odocoileus viginianus)	M1	65	4.174	208	5.338	630.5	6.447	1020.5	6.928	0	????	1
33	Dog (Canis familiaris)	M2 F2	13	2.565	76.7	4.340	110.5	4.705	382.2	5.946	122.2	4.806	
34	Elephant (Loxondonta africana)	M1	6600	8.795	5280	8.572	25740	10.156	106920	11.580	137280	11.830	14,5
35	Fox, gray (Urocyon cineroargeneus)	M1	3.8	1.335	37.62	3.628	22.04	3.093	51.3	3.938	19.38	2.964	
36	Fox, red (Vulpes fulva)	F1	4.6	1.526	52.9	3.968	41.4	3.723	0	????	0	????	
37	Gazelle (Gazella thomsoni)	M2	24	3.178	91.2	4.513	240	5.481	516	6.246	276	5.620	
38	Giraffe (Giraffa camelopardalis)	F1	1200	7.090	720	6.579	4920	8.501	18720	9.837	11880	9.383	2,6
39	Goat (Capra hircus)	F1	28	3.332	114.8	4.743	0	????	532	6.277	0	????	
40	Gorilla (Gorilla gorilla)	M1	180	5.193	0	????	0	????	0	????	0	????	3

41	Guinea pig (Cavia porcellus)	M58	0.26	-1.347	3.458	1.241	1.378	0.321	13.364	2.593	3.068	1.121	0.5
42	Guinea pig (C. porcellus)	F10	0.43	-0.844	3.956	1.375	1.677	0.517	16.598	2.809	4.601	1.526	0.9
43	Hamster, golden (Mesocricetus auratus)	M2 F2	0.12	-2.120	1.056	0.054	0.564	-0.573	6.192	1.823	0.552	-0.594	0.2
44	Hare, African (Lepus capensis)	F1	2.9	1.065	10.15	2.317	29.58	3.387	51.33	3.938	17.69	2.873	6.3
45	Hippopotamus (Hippopotamus amphibius)	F1	1350	7.208	675	6.515	4590	8.432	23625	10.070	11340	9.336	2,976.2
46	Horse, Percheron (Equus caballus)	M1	635	6.454	635	6.454	5588	8.628	8509	9.049	5715	8.651	1,399.9
47	Horse, Percheron (E. caballus)	F1	770	6.646	616	6.423	4697	8.455	6699	8.810	5390	8.592	1,697.5
48	Hyena, spotted (Crocuta crocuta)	M2	62	4.127	173.6	5.157	446.4	6.101	3174.4	8.063	6770.4	8.820	136.6
49	Hyrax (Heterohyrax brucei)	M1	0.75	-0.288	12.3	2.510	3.6	1.281	31.5	3.450	5.55	1.714	1.6
50	Jackal (Canis mesomelas)	M2	2.8	1.030	45.08	3.808	21	3.045	120.4	4.791	29.4	3.381	6.1
51	Jaguar (Felis onca)	F1	34	3.526	146.2	4.985	183.6	5.213	880.6	6.781	567.8	6.342	74.9
52	Kinkajou (Potos flavus)	F1	2.6	0.956	30.68	3.424	14.04	2.642	97.76	4.583	77.74	4.353	5.7
53	Lemming, rock (Dicrostonyx rubricatus)	M4	0.05	-2.996	0.085	-2.465	0.295	-1.221	2.525	0.926	0.795	-0.229	0.1
54	Leopard (Panthera pardus)	M1	48	3.871	134.4	4.901	201.6	5.306	897.6	6.800	499.2	6.213	105.8
55	Lion (P. leo)	M4	125	4.828	237.5	5.470	1062.5	6.968	0	????	2650	7.882	275.5
56	Lion (P. leo)	F3	97	4.575	194	5.268	523.8	6.261	3142.8	8.053	1998.2	7.600	213.8

57	Lynx (Lynx baileyi)	M1	7.4	2.001	0	????	0	????	0	????	0	????	
58	Manatee (Trichechus manatus)	M1	425	6.052	340	5.829	1232.5	7.117	5525	8.617	3060	8.026	9
59	Manatee (T. manatus)	F1	560	6.328	0	????	1232	7.116	6272	8.744	3752	8.230	1,2
60	Mole (Scalopus aquaticus)	M1	0.04	-3.219	1.172	0.159	0.276	-1.287	1.564	0.447	0.744	-0.296	
61	Mongoose (Ichneumia albicauda)	M1	4.4	1.482	28.16	3.338	28.16	3.338	61.16	4.113	58.08	4.062	
62	Monkey, blackhowler(Alouatta palliata)	MF 28	6.2	1.825	50.22	3.916	20.46	3.018	201.5	5.306	39.06	3.665	
63	Monkey, rhesus (Macaca mulatta)	M4	3.3	1.194	91.74	4.519	12.54	2.529	68.97	4.234	0	????	
64	Monkey, rhesus (M. mulatta)	F7	3.6	1.281	92.52	4.527	12.24	2.505	0	????	68.04	4.220	
65	Mouse, jumping (Zapus hudsonicus)	M1 F3	0.018	-4.017	0.6426	-0.442	0.1854	-1.685	1.0134	0.013	0.2412	-1.422	
66	Mouse, meadow (Microtus drummondi)	MF 67	0.023	-3.772	0.0667	-2.708	0.1564	-1.855	1.0488	0.048	0.391	-0.939	
67	Muskrat (Ondatra zibethica)	M1	0.9	-0.105	5.31	1.670	3.24	1.176	21.96	3.089	4.32	1.463	
68	Opossum, woolly (Philander laniger)	M1 F1	190	5.247	0	????	3002	8.007	9006	9.106	3002	8.007	4
69	Porcupine (Erethizon dorsatum)	M1 F3	2.9	1.065	22.62	3.119	15.95	2.769	116	4.754	28.42	3.347	
70	Porpoise (Phocaena phocaena)	M1	140	4.942	1708	7.443	728	6.590	2912	7.977	5166	8.550	3

71	Rabbit, giant Flemish (Lepus spp)	M2	3.7	1.308	10.73	2.373	10.73	2.373	98.42	4.589	0	????	8.1
72	Rabbit, giant Flemish (Lepus app)	F22	2.5	0.916	10	2.303	8.75	2.169	79.75	4.379	13.25	2.584	5.5
73	Raccoon (Procyon lotor)	M1	5.2	1.649	42.64	3.753	42.12	3.741	186.16	5.227	186.16	5.227	11.4
74	Raccoon (P. lotor)	F1	2.2	0.788	33.22	3.503	19.58	2.975	138.38	4.930	19.14	2.952	4.8
75	Rat, Norway (Rattus norvegicus)	M2 F1	0.25	-1.386	3.05	1.115	1.3	0.262	8.375	2.125	1.975	0.681	0.5
76	Reedbuck (Redunca redunca)	M2	31	3.434	105.4	4.658	235.6	5.462	511.5	6.237	415.4	6.029	68.3
77	Seal, ringed (Phoca hispida)	M3 F2	39	3.664	245.7	5.504	284.7	5.651	1095.9	6.999	721.5	6.581	85.9
78	Shrew (Blarina brevicauda)	M2 9	0.02	-3.912	0.374	-0.983	0.204	-1.590	1.162	0.150	0.448	-0.803	0.0
79	Shrew (Blarina brevicauda)	F39	0.01 7	-4.075	0.3587	-1.025	0.1785	-1.723	0.9265	-0.076	0.3723	-0.988	0.0
80	Skunk (Mephitis mephitis)	M1 F2	2.1	0.742	6.93	1.936	12.18	2.500	56.49	4.034	33.39	3.508	4.6
81	Sloth (three-toed (Bradypus tridactylus)	MF 6	1.8	0.588	13.5	2.603	0	????	0	????	0	????	3.9
82	Squirrel, red (sciurus hudsonicus)	M4	0.18	-1.715	4.626	1.532	1.548	0.437	3.924	1.367	2.61	0.959	0.4
83	Squirrel, red (s. husdonicus)	F4	0.25	-1.386	5.05	1.619	1.825	0.602	6.7	1.902	3.2	1.163	0.5
84	Steinbok (Raphicerus campestris)	M2	8.6	2.152	49.02	3.892	72.24	4.280	174.58	5.162	149.64	5.008	18.9
85	Swine (Sus scrofa)	F36	102	4.625	0	????	326.4	5.788	1540.2	7.340	0	????	224.8
86	Tapir (Tapirella bairdii)	M1 F1	11.4	2.434	0	????	96.9	4.574	349.98	5.858	239.4	5.478	25.1

87	Tiger (Panthera tigris)	F1	160	5.075	224	5.412	432	6.068	1824	7.509	1024	6.931	3
88	Walrus (Odobenus rosmarus)	M1 F3	600	6.397	1020	6.928	4080	8.314	17520	9.771	8160	9.007	1,3
89	Warthog (Phacochoerus aethiopicus)	M1	65	4.174	123.5	4.816	325	5.784	1495	7.310	546	6.303	1
90	Weasel, arctic (Mustela arctica)	M3 F1	0.18	-1.715	5.04	1.617	3.078	1.124	8.532	2.144	3.744	1.320	
91	Whale, white (Delphiapterus leucas)	M4	447	6.103	2324.4	7.751	2458.5	7.807	6794.4	8.824	12069	9.398	9
92	Whale, white (Delphiapterus leucas)	F2	300	5.704	2340	7.758	1710	7.444	4770	8.470	7860	8.970	6
93	Wildebeest (Connochaetes taurinus)	M2	210	5.347	441	6.089	1302	7.172	2247	7.717	2814	7.942	4
94	Wolf (Canis lupus)	M1	22	3.091	114.4	4.740	237.6	5.471	607.2	6.409	783.2	6.663	
95	Zebra (Equus quagga)	M3 F1	280	5.635	560	6.328	3976	8.288	4676	8.450	2240	7.714	6
96	Blackbird (Quiscalus quiscala)	F1	0.08	-2.526	2.848	1.047	0.112	-2.189	2.568	0.943	0.168	-1.784	
97	Bluebird (Sialia sialis)	M1 F1	0.03	-3.507	1.272	0.241	0.417	-0.875	0	????	0	????	
98	Buzzard, steppe (Buteo vulpinus)	M1	0.56	-0.580	7.896	2.066	4.592	1.524	10.864	2.385	4.648	1.536	
99	Catbird (Dumatella carolinensis)	F1	0.03	-3.507	0.129	-2.048	0.297	-1.214	0	????	0.552	-0.594	
100	Canary (Serinus canarius)	M1 F1	0.016	-4.135	0.7552	-0.281	0.2064	-1.578	0.8624	-0.148	0.024	-3.730	

101	Cowbird (Molothrus ater)	F1	0.07	-2.659	2.856	1.049	1.127	0.120	0	????	0	????	0.1
102	Crane, gray (Grus canadensis)	M1	1.6	0.470	8.32	2.119	18.4	2.912	28.48	3.349	14.88	2.700	3.5
103	Crow (Corvus brachyrhyncos)	M1	0.33	-1.109	9.108	2.209	3.135	1.143	0	????	9.768	2.279	0.7
104	Duck, pintail (Anas acuta)	F1	0.67	-0.400	4.958	1.601	8.308	2.117	30.351	3.413	17.152	2.842	1.4
105	Eagle, tawny (Aguila rapax)	M2 F3	2.4	0.875	14.16	2.650	15.12	2.716	43.68	3.777	24.96	3.217	5.2
106	Egret, great white (Casmerodius albus)	F1	10	2.303	59	4.078	90	4.500	320	5.768	321	5.771	22.0
107	Flamingo (Phoeniconaias minor)	M3 F2	15	2.708	73.5	4.297	141	4.949	402	5.996	220.5	5.396	33.0
108	Fowl, domestic (Gallus domesticus)	M8	0.73	-0.315	2.92	1.072	4.161	1.426	16.133	2.781	4.38	1.477	1.6
109	Fowl, domestic (Gallus domesticus)	F16	0.61	-0.494	2.684	0.987	3.843	1.346	14.396	2.667	3.721	1.314	1.3
110	Fowl, white leghorn, "germ-free"	?	.9-1.2	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!	#VALUE!
111	Goose, Egyptian (Alopochen aegypticus)	F1	1.9	0.642	7.41	2.003	18.24	2.904	33.63	3.515	34.2	3.532	4.1
112	Guineafowl (Numida meleagris)	M1	1.6	0.470	4.16	1.426	14.08	2.645	28.16	3.338	28.64	3.355	3.5
113	Gull, herring (Larus argentatus)	F2	0.53	-0.635	5.035	1.616	5.194	1.648	27.136	3.301	0	????	1.1

114	Hawk, red-tailed (Buteo borealis)	F3	1	0.000	9.7	2.272	6.7	1.902	13.7	2.617	9	2.197	
115	Hummingbird (Amazilia tzacatl)	F1	0.005	-5.298	0.208	-1.570	0.1185	-2.133	0.2615	-1.341	0.01	-4.605	
116	Ostrich, masai (Struthio camelus)	M1	125	4.828	37.5	3.624	1225	7.111	2075	7.638	2950	7.990	2
117	Owl, honed (Buteo viginianus)	M1	1.2	0.182	13.92	2.633	8.76	2.170	0	????	10.92	2.391	
118	Partridge (Francolinus sephaena)	M1	0.21	-1.561	1.512	0.413	1.47	0.385	8.736	2.167	0	????	
119	Pelican (Pelecanus occidentalis)	F2	3.3	1.194	17.82	2.880	22.11	3.096	73.26	4.294	30.03	3.402	
120	Pheasant (Phasianus cochicus)	M1	0.62	-0.478	3.286	1.190	5.58	1.719	9.052	2.203	0	????	
121	Pigeon (Columba livia)	M3 F1	0.27	-1.309	2.565	0.942	4.725	1.553	4.752	1.559	0	????	
122	Raven (Corvus corax)	F1	1.25	0.223	35.125	3.559	10.625	2.363	0	????	0	????	
123	Robin (Turdus migratorius)	M2	0.07	-2.659	2.107	0.745	1.022	0.022	0	????	1.694	0.527	
124	Sparrow (Passer domesticus)	M75	0.024	-3.730	1.0464	0.045	0.4152	-0.879	1.2288	0.206	0.3744	-0.982	
125	Sparrow (Passer domesticus)	F11	0.023	-3.772	1.0074	0.007	0.3887	-0.945	1.0741	0.071	0.3956	-0.927	
126	Starling (Sturnus vulgaris)	M15	0.06	-2.813	1.956	0.671	0.972	-0.028	2.076	0.730	1.122	0.115	

127	Starling (Sturnus vulgaris)	F10	0.06	-2.813	1.878	0.630	0.894	-0.112	2.256	0.814	1.122	0.115	0.1
128	Stork, European (Ciconia ciconia)	M2 F1	3.3	1.194	15.51	2.741	30.36	3.413	63.36	4.149	36.63	3.601	7.2
129	Alligator (Alligator mississipiensis)	M2	190	5.247	13.3	2.588	285	5.652	722	6.582	1026	6.933	418.8
130	Crocodile (Crocodylus acutus)	M1 F1	110	4.700	11	2.398	132	4.883	1122	7.023	1100	7.003	242.5
131	Iguana lizard (Iguana iguana)	F1	1.3	0.262	0	????	2.47	0.904	32.37	3.477	3.64	1.292	2.8
132	Lizard (Lacerta viridis)	MF 15	0.05	-2.996	0.12	-2.120	0.06	-2.813	2.5	0.916	0	????	0.1
133	Snake, black (Coluber constrictor)	M1 F2	0.43	-0.844	0.301	-1.201	0.946	-0.056	2.58	0.948	3.44	1.235	0.9
134	Snake, boa (Boa imperator)	F1	1.8	0.588	0.36	-1.022	5.58	1.719	29.88	3.397	13.68	2.616	3.9
135	Snake, green (Zamenis viridis)	M3 F3	0.02 2	-3.817	0.209	-1.565	0	????	0.4818	-0.730	0	????	0.0
136	Snake, python (Python molurus)	M1	6.1	1.808	1.22	0.199	18.3	2.907	0	????	0	????	13.4
137	Snake, watermoccasin (Ancistrododon pisci)	F1	0.73	-0.315	0.657	-0.420	4.745	1.557	64.605	4.168	22.776	3.126	1.6
138	Toad, horned (Phrynosoma cornutum)	M2 F3	0.02 5	-3.689	0.13	-2.040	0.11	-2.207	0	????	0	????	0.0

139	Turtle (Aromochelys tristycha)	M1	0.12	-2.120	0	????	0.516	-0.662	3.36	1.212	1.02	0.020	
140	Turtle (Aromochelys tristycha)	F2	0.09	-2.408	0	????	0.432	-0.839	2.61	0.959	0.684	-0.380	
141	Turtle (Testudo graeca)	MF30	0.32	-1.139	0.288	-1.245	0	????	8.512	2.141	0	????	
142	Turtle, cumberland (Chrysemys elegans)	M21	0.84	-0.174	0	????	2.688	0.989	45.612	3.820	8.988	2.196	
143	Turtle, cumberland (Chrysemys elegans)	F1	0.86	-0.151	0	????	2.666	0.981	50.912	3.930	7.224	1.977	
144	Frog, bull (Rana catesbiana)	M7	0.49	-0.713	4.557	1.517	1.568	0.450	13.475	2.601	2.597	0.954	
145	Frog, leopard (R. pipiens)	M10	0.036	-3.324	0	????	0.1548	-1.866	1.0116	0.012	0.306	-1.184	
146	Frog, leopard (R. pipiens)	F19	0.038	-3.270	0	????	0.1824	-1.702	1.0944	0.090	0.2888	-1.242	
147	Barracuda (Sphyraena barracuda)	M3F3	8.8	2.175	3.52	1.258	21.12	3.050	60.72	4.106	0	????	
148	Carp (Cyprinus carpio)	M2F4	1.05	0.049	1.26	0.231	1.575	0.454	0	????	0	????	
149	Codfish (Gadus morrhua)	F1	10.6	2.361	5.3	1.668	15.9	2.766	161.12	5.082	0	????	
150	Haddock (G. aeglefinus)	F6	3.3	1.194	1.98	0.683	5.61	1.725	133.65	4.895	0	????	
151	Mackerel (Scomber vernalis)	M1	0.76	-0.274	0.608	-0.498	0	????	0	????	0	????	
152	Mackerel (Scomber vernalis)	F2	1.5	0.405	1.65	0.501	3	1.099	6.45	1.864	0	????	

153	Perch (Perca flavescens)	M6	0.17	-1.772	0.255	-1.366	0.391	-0.939	1.496	0.403	0	????	0.3
154	Perch (Perca flavescens)	F1	0.19	-1.661	0.323	-1.130	1.463	0.380	2.926	1.074	0	????	0.4
155	Pike (Esox lucius)	M4 F3	0.42	-0.868	0.504	-0.685	0.63	-0.462	3.612	1.284	0	????	0.9
156	Salmon (Salmo salar)	M3	3.4	1.224	1.02	0.020	12.24	2.505	68.68	4.229	0	????	7.5
157	Salmon (Salmo salar)	F5	5.4	1.686	1.08	0.077	10.26	2.328	93.42	4.537	0	????	11.9
158	Trout, rainbow (Salmo irideus)	M2	0.26	-1.347	0.442	-0.816	0.442	-0.816	2.574	0.945	0	????	0.5
159	Trout, rainbow (Salmo irideus)	F4	0.22	-1.514	0.418	-0.872	0.286	-1.252	2.178	0.778	0	????	0.4

Describe the relation between gross national product and military expenditures (1975 data). (World Handbook of Social and Political Indicaqtors.***)

"COUNTRY NAME"	"TOT DEFENSE EXP,75"	"GROSS NAT PRODUCT,75"	ln(GNP)	ln(Defense)
AFGN	37	2060	7.630	3.611
ALBN	131	1220	7.107	4.875
ALGR	302	13680	9.524	5.710
ANGL	97	2030	7.616	4.575
ARGN	860	39330	10.580	6.757
AUSL	2480	77010	11.252	7.816
AUST	357	36650	10.509	5.878
BHMS		630		
BHRN	14	580	6.363	2.639
BHTN		80		
BLGM	1720	61470	11.026	7.450
BLGR	1680	18420	9.821	7.427
BNGL	76	7280	8.893	4.331
BNIN	6	390	5.966	1.792
BOLV	59	2040	7.621	4.078

BRBD	1	350	5.858	0.000
BRMA	171	3320	8.108	5.142
BRND	9	410	6.016	2.197
BRZL	2440	110130	11.609	7.800
BTSN	0	230		
CAFR	8	390	5.966	2.079
CHAD	23	460	6.131	3.135
CHLE	331	10130	9.223	5.802
CHNA	32800	315250	12.661	10.398
CLMB	165	13630	9.520	5.106
CMRN	34	2050	7.626	3.526
CMRS		70		
CNDA	3160	158100	11.971	8.058
CNGO	26	670	6.507	3.258
CRCA	0	1890		
CUBA	393	7460	8.917	5.974
CVRD		80		
CYPR	21	780	6.659	3.045
CZCH	3180	53450	10.887	8.065
DMNR	46	3390	8.129	3.829
DNMK	858	34450	10.447	6.755
ECDR	75	4180	8.338	4.317
EGPT	1340	9540	9.163	7.200
ELSL	21	1830	7.512	3.045
EQGN	5	100	4.605	1.609
ETHP	110	2730	7.912	4.700
FIJI	1	620	6.430	0.000
FNLD	348	25520	10.147	5.852
FRG	14700	412480	12.930	9.596
FRNC	11400	314080	12.657	9.341
GBON	14	1360	7.215	2.639
GDR	3890	65830	11.095	8.266
GHNA	71	5860	8.676	4.263
GMBA	0	90		
GNBS	0	70		
GNEA	21	750	6.620	3.045
GRCE	1430	21320	9.967	7.265

GRND		40		
GTML	44	3590	8.186	3.784
GYNA	11	400	5.991	2.398
HATI	9	850	6.745	2.197
HGKG		7700		
HNDS	18	1050	6.957	2.890
HNGR	1420	22690	10.030	7.258
ICLD	0	1320		
INDA	3310	85960	11.362	8.105
INDS	1050	29120	10.279	6.957
IRAN	7760	55510	10.924	8.957
IRAQ	1850	13880	9.538	7.523
IRLD	102	7470	8.919	4.625
ISRL	4160	13160	9.485	8.333
ITLY	4440	156590	11.961	8.398
IVCT	53	3630	8.197	3.970
JMCA	16	2270	7.728	2.773
JPAN	4780	496260	13.115	8.472
JRDN	144	1240	7.123	4.970
KMPC	68			
KNYA	51	2970	7.996	3.932
KORN	729	7100	8.868	6.592
KORS	991	19850	9.896	6.899
KWAT	235	15270	9.634	5.460
LAOS	19	300	5.704	2.944
LBNN	136	3290	8.099	4.913
LBRA	4	640	6.461	1.386
LBYA	201	13510	9.511	5.303
LSTO	0	190		
LXBG	23	2150	7.673	3.135
MALI	14	530	6.273	2.639
MDGS	28	1720	7.450	3.332
MLDV		10		
MLTA	2	460	6.131	0.693
MLWI	5	660	6.492	1.609
MLYS	515	9340	9.142	6.244
MNGL	74	1250	7.131	4.304

MRCO	253	7860	8.970	5.533
MRTN	8	420	6.040	2.079
MRTS	1	540	6.292	0.000
MXCO	528	63200	11.054	6.269
MZBQ	0	1640		
NCRG	32	1580	7.365	3.466
NGER	4	590	6.380	1.386
NGRA	1070	25600	10.150	6.975
NPAL	9	1340	7.200	2.197
NRWY	847	27110	10.208	6.742
NTHL	2660	78550	11.271	7.886
NZLD	262	13130	9.483	5.568
OMAN	655	1790	7.490	6.485
PERU	621	11670	9.365	6.431
PHLP	402	15930	9.676	5.996
PKST	622	11270	9.330	6.433
PLND	5090	88320	11.389	8.535
PNMA	15	2150	7.673	2.708
PPNG		1290		
PRGY	23	1470	7.293	3.135
PRTG	1000	15060	9.620	6.908
PRTR		7120		
QTAR	106	2200	7.696	4.663
RMNA	2230	26450	10.183	7.710
RWND	7	430	6.064	1.946
SAFR	1520	32270	10.382	7.326
SDAN	121	4140	8.328	4.796
SDAR	1750	33240	10.412	7.467
SMLA	21	340	5.829	3.045
SNGL	29	1800	7.496	3.367
SNGP	305	5510	8.614	5.720
SPAN	2820	97140	11.484	7.944
SRLE	5	610	6.413	1.609
SRLK	23	2540	7.840	3.135
SRNM	0	500		
STPR		40		
SWAZ	0	220		

SWDN	1980	66830	11.110	7.591
SWTZ	964	53840	10.894	6.871
SYCH		30		
SYRA	837	5330	8.581	6.730
TLND	398	14600	9.589	5.986
TNSA	65	4090	8.316	4.174
TNZN	65	2440	7.800	4.174
TOGO	8	560	6.328	2.079
TRKY	1600	36030	10.492	7.378
TRNT	6	2170	7.682	1.792
TWAN	1410	14890	9.608	7.251
UAR	59	8880	9.092	4.078
UGND	78	2680	7.894	4.357
UK	10200	211700	12.263	9.230
UPVL	13	640	6.461	2.565
URGY	73	3600	8.189	4.290
USA	91000	1519890	14.234	11.419
USSR	119000	649470	13.384	11.687
VNM				
VNMN	310			
VNMS	465			
VNZL	539	27320	10.215	6.290
WSMA		50		
YGSL	1600	33080	10.407	7.378
YMNA	37	410	6.016	3.611
YMNS	52	1210	7.098	3.951
ZAIR	143	3450	8.146	4.963
ZIMB	81	3460	8.149	4.394
ZMBA	94	2090	7.645	4.543

What is the correspondence between the quantity of labor (number of employees) and the quantity of capital (assets) among petroleum refiining companies?

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COMPANY	REVENUES	PROFITS	ASSETS	EMPLOYEES	INDUSTRY
Name	$ millions	$ millions	$ millions		
Exxon	110,009.0	6,470.0	91,296.0	82,000	Petroleum refining
Mobil	66,724.0	2,376.0	42,138.0	50,400	Petroleum refining
Texaco	36,787.0	607.0	24,937.0	28,247	Petroleum refining
Chevron	32,094.0	930.0	34,330.0	43,019	Petroleum refining
Amoco	27,665.0	1,862.0	29,845.0	42,689	Petroleum refining
USX	18,214.0	214.0	16,743.0	42,774	Petroleum refining
Atlantic Richfield	16,739.0	1,376.0	23,999.0	22,000	Petroleum refining
Phillips Petroleum	13,521.0	469.0	11,978.0	17,400	Petroleum refining
Ashland	11,251.1	23.9	6,991.6	32,800	Petroleum refining
Coastal	10,223.4	270.4	10,658.8	15,500	Petroleum refining
Sun	8,370.0	140.0	5,184.0	11,995	Petroleum refining
Unocal	7,527.0	260.3	9,891.0	12,509	Petroleum refining
Amerada Hess	7,524.8	(394.4)	7,756.4	9,574	Petroleum refining
Tosco	7,284.1	77.1	2,003.2	3,750	Petroleum refining
MAPCO	3,310.0	74.7	2,293.3	6,204	Petroleum refining
Valero Energy	3,019.8	59.8	2,876.7	1,658	Petroleum refining
Diamond Shamrock	2,956.7	47.3	2,245.4	11,250	Petroleum refining
Kerr-McGee	2,928.0	(31.2)	3,232.0	3,976	Petroleum refining
Ultramar	2,714.4	69.6	1,971.3	2,800	Petroleum refining
Pennzoil	2,490.0	(305.1)	4,307.8	9,758	Petroleum refining